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ALEXANDER GS TAILRACE PIERS
CAMERON FALLS GS MAIN DAM
CONCRETE INVESTIGATION

Report No 88-196-K

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ABSTRACT

An investigation into the deterioration of the concrete in the tailrace piers at Alexander GS and the sluiceway piers at Cameron Falls GS established that the primary cause of deterioration is freeze-thaw cycling of the concrete in a saturated state. It was also determined that a very poor bond exists between a repair slab and the original concrete of the east gravity section at Cameron Falls GS.

Consideration should be given to repair the tailrace piers at Alexander GS and the sluiceway piers, the east abutment pier and the gravity section at Cameron Falls GS.

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To: Mr. O. Bernaus
Civil Maintenance Manager
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Attn: Mr. L.W. Coley

ALEXANDER GS TAILRACE PIERS
CAMERON FALLS GS MAIN DAM
CONCRETE INVESTIGATION

1.0 INTRODUCTION

At the request of Mr. T.W. Frost of the Civil Works Department, an investigation into the deterioration of concrete at Alexander GS and Cameron Falls GS was conducted by the Concrete Technology Section, Civil Research Department. The specific areas investigated were the tailrace piers at Alexander GS and the sluiceway piers and the repaired portion of the gravity section of the main dam, east of the powerhouse, at Cameron Falls GS.

The investigation consisted of concrete coring to determine the depth of deterioration and to obtain specimens for laboratory testing. Visual observations were also made to assess the extent of deterioration. The drilling operation was carried out from June 6 to 17, 1988.

The results of this investigation, including the laboratory testing of the cores, are given in this report.

2.0 CONCRETE CORING

2.1 Procedure

The drilling was performed with a 100 mm nominal diameter water-cooled diamond bit drill.

Five horizontal cores were drilled from the Alexander GS tailrace piers. One of these (Core 1) was obtained from relatively sound concrete and the others (Cores 2 to 5) from deteriorated sections of the piers. A core log is given in Appendix A.

Twelve cores were obtained from Cameron Falls GS: two (Cores 1 and 2) were drilled to investigate the condition of the concrete associated with a large crack in the east abutment pier of the sluiceway; eight (Cores 3 to 10) were

from deteriorated sections of the sluiceway piers; and two (Cores 11 and 12) were drilled to determine the condition of a repair to the gravity section east of the powerhouse. A core log is given in Appendix B.

2.2 Laboratory Testing

The laboratory investigation consisted of selecting specimens from the cores and testing in accordance with the applicable CSA and ASTM standards for the following properties:

Compressive Strength	CSA A23.2
Ultrasonic Pulse Velocity	ASTM C 597
Density	ASTM C 642
Absorption	ASTM C 642
Microscopic Examination	--

A summary of the test results is given in Figures 1, 2 and 3.

3.0 OBSERVATIONS AND DISCUSSION

3.1 Alexander GS

The deterioration of the concrete in the tailrace piers at Alexander GS is shown in Figures 4 and 5. The exposed concrete on the downstream face has cracked and spalled, exposing reinforcing steel at some locations. The depth of spalling extends up to 230 mm from the original surface of the piers and is most severe at the waterline. The freeze-thaw damage, observed in the cores, extends up to 160 mm into the concrete at some locations (Figure 6).

The results of tests on the cores (Figure 1) indicate that the concrete, except for the freeze-thaw damaged portion, is of good quality. The compressive strength ranged from 17.4 to 35.7 MPa, and the ultrasonic pulse velocity and density were in the range generally associated with good quality concrete. The absorption of the concrete in Cores 4 and 5 was above the normal range of 4% to 6%, which indicates potential durability problems. A cursory microscopic examination of a portion of Core 2 confirmed that the concrete is not air-entrained.

3.2 Cameron Falls GS

At Cameron Falls GS, a large crack extends diagonally through the top portion of the sluiceway east abutment pier. Where the crack intersects the surface of the pier, the concrete has spalled. Damage has also occurred on the west side of the pier at the seat supporting the deck slab. Figures 7 and 8 show the location of the crack. The test results indicate a good quality concrete. Some erosion and freeze-thaw damage was evident in one of the cores.

The sluiceway piers exhibit extensive localized deterioration. As shown in Figures 9 and 10, the upper portion of the piers appear sound; however, some of the piers contain cracks that extend at least 150 mm into the concrete (Figure 11). In the lower portion, below a horizontal construction joint, the concrete has spalled and is extensively deteriorated.

Although the surface of the piers have spalled and deteriorated, the test results indicate that the concrete beyond the damaged portion is sound with compressive strengths ranging from 26.1 to 47.4 MPa. The absorption was high in some of the cores, particularly Core 8 that was composed primarily of mortar with virtually no large aggregate. A cursory microscopic examination of specimens from Cores 2 and 9 determined that the concrete is not air-entrained.

The gravity section of the main dam, adjacent to the powerhouse, was repaired in 1957. The repair consisted of placing a 760 mm thick concrete slab on the downstream face. Several cracks are present in this slab including extensive deposits from water leaching the concrete through joints and cracks. At some locations these deposits are up to 25 mm thick. Two cores were drilled through the repair into the original concrete (Figure 12). When the first hole (Core 11) had been completed, water was observed to be flowing from it at a rate of 4.5 l/min. Once the second hole (Core 12) had been drilled, the flow at the first hole stopped, and a flow of 18 l/min was observed at the second hole (Figure 13). Core 12 was drilled below and to the south of Core 11.

In the cores, the interface between the repair and the original concrete was not retrieved intact. The original concrete at the interface was retrieved as rubble or showed evidence of freeze-thaw damage. Based on these observations, including the presence of water flowing from the drill holes, it is evident that a very poor bond, if any, exists between the repair and original concretes.

The tests conducted on sections of the repair concrete (Figure 3) indicate that it is of good quality with an average compressive strength of 37.8 MPa. The original concrete, not damaged by freeze-thaw action, was also sound with a compressive strength of 36.1 MPa.

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 The deterioration of the tailrace piers at Alexander GS extends to a maximum depth of 360 mm into the concrete. Freeze-thaw cycling and the erosive action of water and ice are causing the deterioration of the piers. This deterioration is progressive and will continue.

4.2 The large crack in the sluiceway east abutment pier at Cameron Falls GS appears structural in nature. The stability of this block should be assessed and further deterioration and movement of the crack monitored.

4.3 The localized deterioration of the sluiceway piers of the main dam at Cameron Falls GS extends a maximum of 380 mm into the piers and is caused by freeze-thaw action combined with the erosive action of water and ice. This deterioration is similar to that observed at Alexander GS and is progressive.

4.4 The bond between the repair and original concrete of the main dam gravity section at Cameron Falls GS is poor. Water appears to be flowing along the interface, and a portion of the original concrete is deteriorated. Remedial action is recommended to repair the bond at the concrete to concrete interface and prevent the flow of water along the interface.

4.5 Any repairs carried out to the piers should include the removal of all deteriorated concrete, including that damaged by freeze-thaw action.

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Submitted by:

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EJM:lct

FIGURE 1

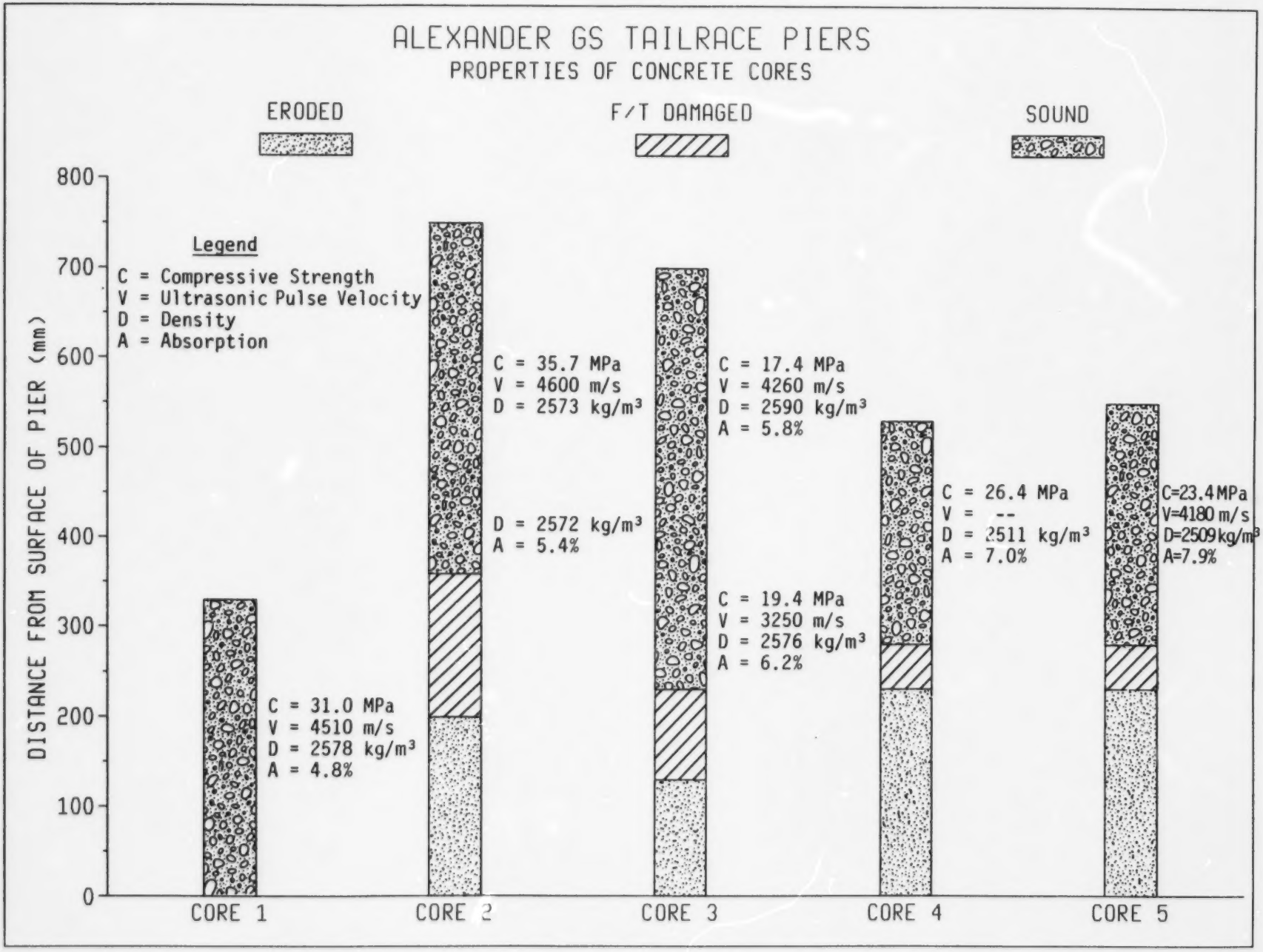

ALEXANDER GS TAILRACE PIERS
PROPERTIES OF CONCRETE CORES
ERODED
F/T DAMAGED
SOUND
Legend
C = Compressive Strength
V = Ultrasonic Pulse Velocity
D = Density
A = Absorption
DISTANCE FROM SURFACE OF PIER (mm)
800
700
600
500
400
300
200
100
0
C = 31.0 MPa
V = 4510 m/s
D = 2578 kg/m³
A = 4.8%
C = 35.7 MPa
V = 4600 m/s
D = 2573 kg/m³
D = 2572 kg/m³
A = 5.4%
C = 17.4 MPa
V = 4260 m/s
D = 2590 kg/m³
A = 5.8%
C = 19.4 MPa
V = 3250 m/s
D = 2576 kg/m³
A = 6.2%
C = 26.4 MPa
V = --
D = 2511 kg/m³
A = 7.0%
C=23.4 MPa
V=4180 m/s
D=2509 kg/m³
A=7.9%
CORE 1
CORE 2
CORE 3
CORE 4
CORE 5

FIGURE 2

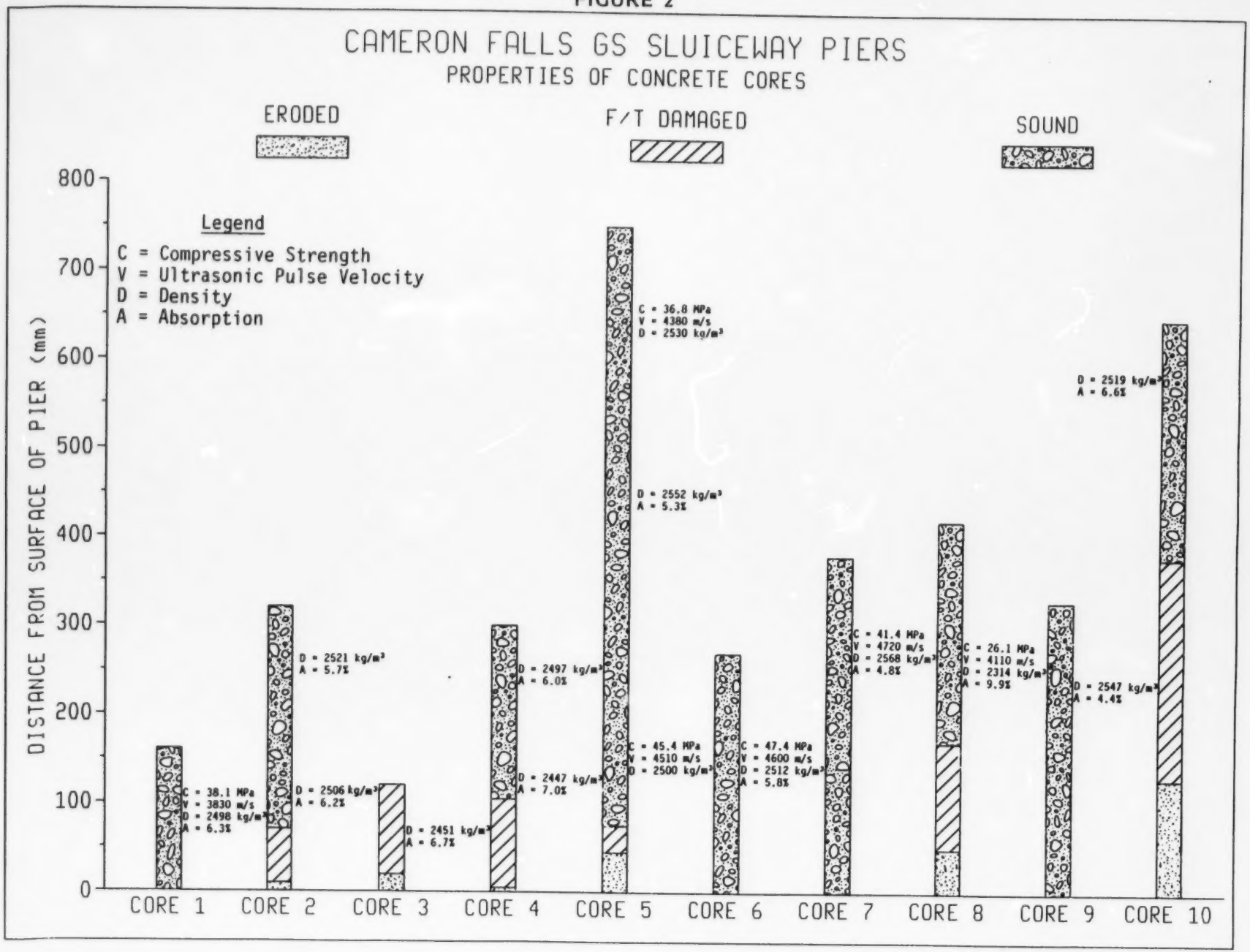
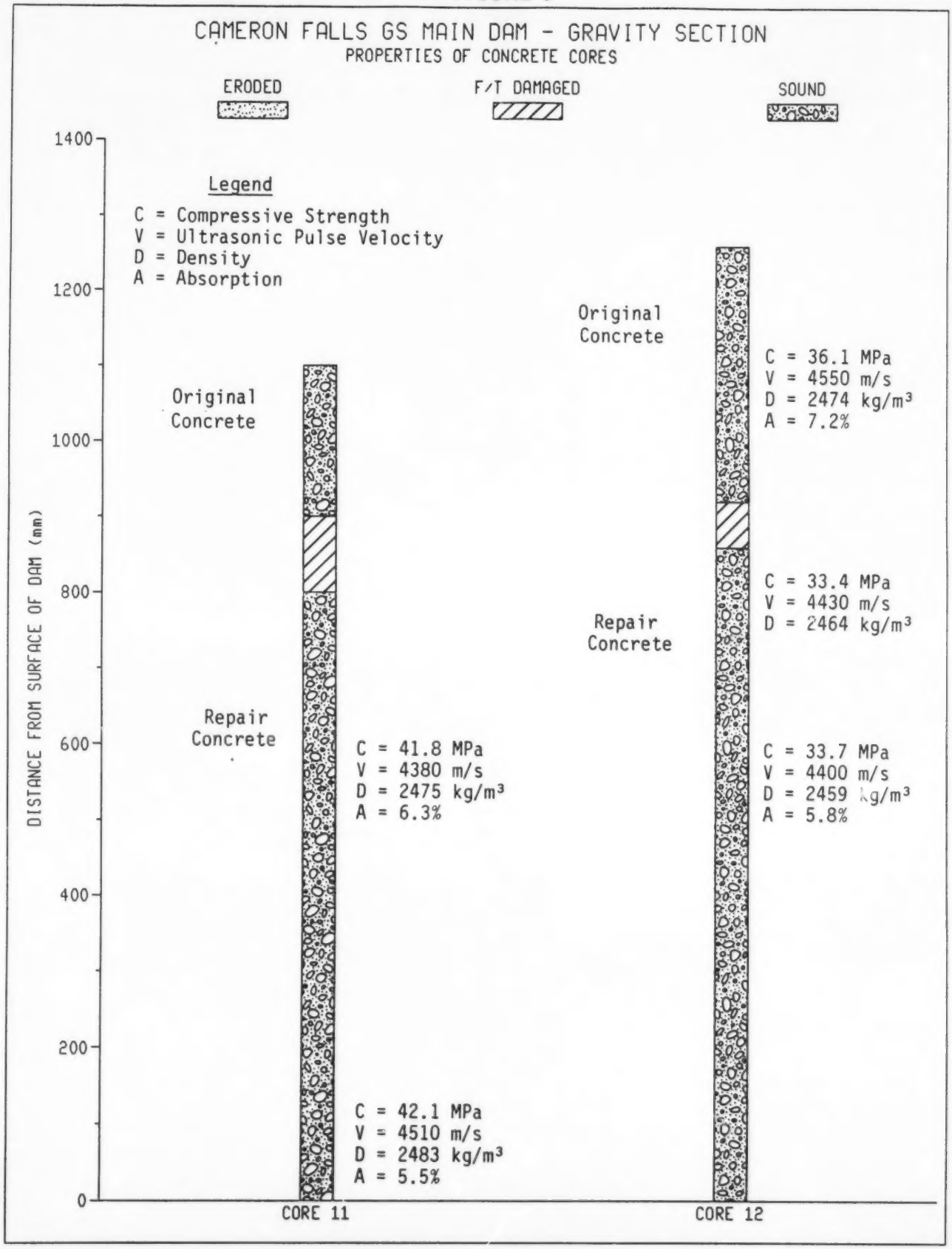

CAMERON FALLS GS SLUICEWAY PIERS
PROPERTIES OF CONCRETE CORES
ERODED
F/T DAMAGED
SOUND
Legend
C = Compressive Strength
V = Ultrasonic Pulse Velocity
D = Density
A = Absorption
DISTANCE FROM SURFACE OF PIER (mm)
0
100
200
300
400
500
600
700
800
C = 38.1 MPa
V = 3830 m/s
D = 2498 kg/m³
A = 6.3%
D = 2521 kg/m³
A = 5.7%
D = 2506 kg/m³
A = 6.2%
D = 2451 kg/m³
A = 6.7%
D = 2497 kg/m³
A = 6.0%
D = 2447 kg/m³
A = 7.0%
C = 36.8 MPa
V = 4380 m/s
D = 2530 kg/m³
D = 2552 kg/m³
A = 5.3%
C = 45.4 MPa
V = 4510 m/s
D = 2500 kg/m³
C = 47.4 MPa
V = 4600 m/s
D = 2512 kg/m³
A = 5.8%
C = 41.4 MPa
V = 4720 m/s
D = 2568 kg/m³
A = 4.8%
C = 26.1 MPa
V = 4110 m/s
D = 2314 kg/m³
A = 9.9%
D = 2519 kg/m³
A = 6.6%
D = 2547 kg/m³
A = 4.4%
CORE 1
CORE 2
CORE 3
CORE 4
CORE 5
CORE 6
CORE 7
CORE 8
CORE 9
CORE 10

FIGURE 3


CAMERON FALLS GS MAIN DAM - GRAVITY SECTION
PROPERTIES OF CONCRETE CORES
ERODED
F/T DAMAGED
SOUND
Legend
C = Compressive Strength
V = Ultrasonic Pulse Velocity
D = Density
A = Absorption
DISTANCE FROM SURFACE OF DAM (mm)
1400
1200
1000
800
600
400
200
0
Original Concrete
Repair Concrete
C = 41.8 MPa
V = 4380 m/s
D = 2475 kg/m³
A = 6.3%
C = 42.1 MPa
V = 4510 m/s
D = 2483 kg/m³
A = 5.5%
CORE 11
Original Concrete
Repair Concrete
C = 36.1 MPa
V = 4550 m/s
D = 2474 kg/m³
A = 7.2%
C = 33.4 MPa
V = 4430 m/s
D = 2464 kg/m³
C = 33.7 MPa
V = 4400 m/s
D = 2459 kg/m³
A = 5.8%
CORE 12

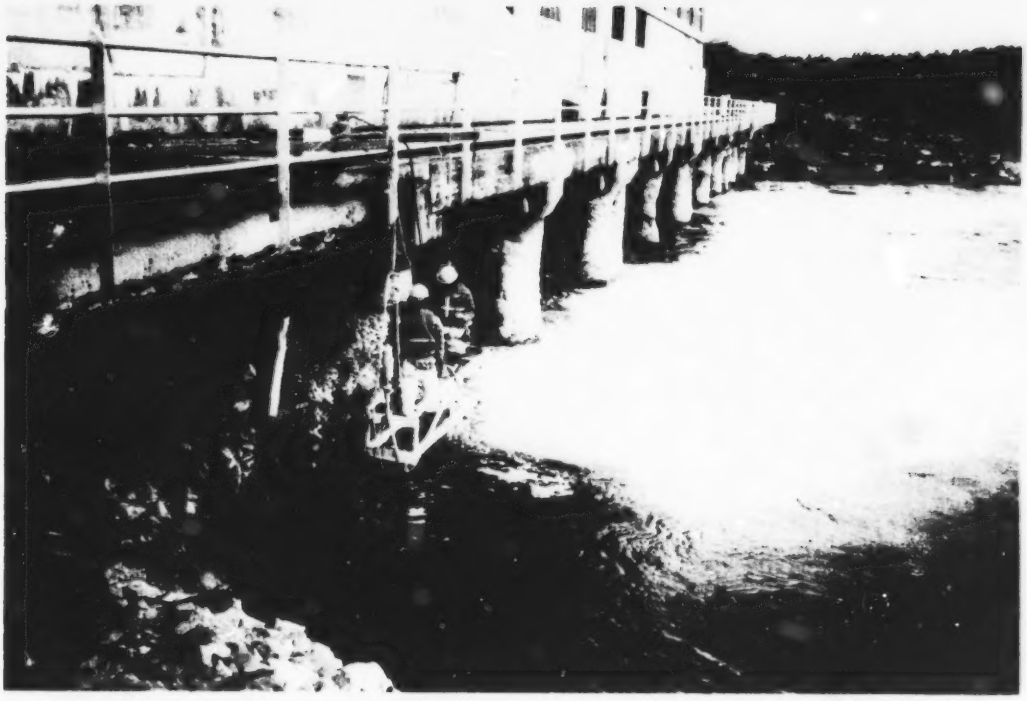


Figure 4: **Alexander GS.** A view of the tailrace piers showing the deterioration at the waterline. Core 2 is being drilled through the deteriorated concrete of Pier 1.

Figure 5: **Alexander GS.** Deterioration of the concrete at the waterline of Pier 1. Core 1 is being drilled in a relatively sound section of concrete.

Figure 6: **Alexander GS.** Evidence of freeze-thaw damage to a section of Core 2.

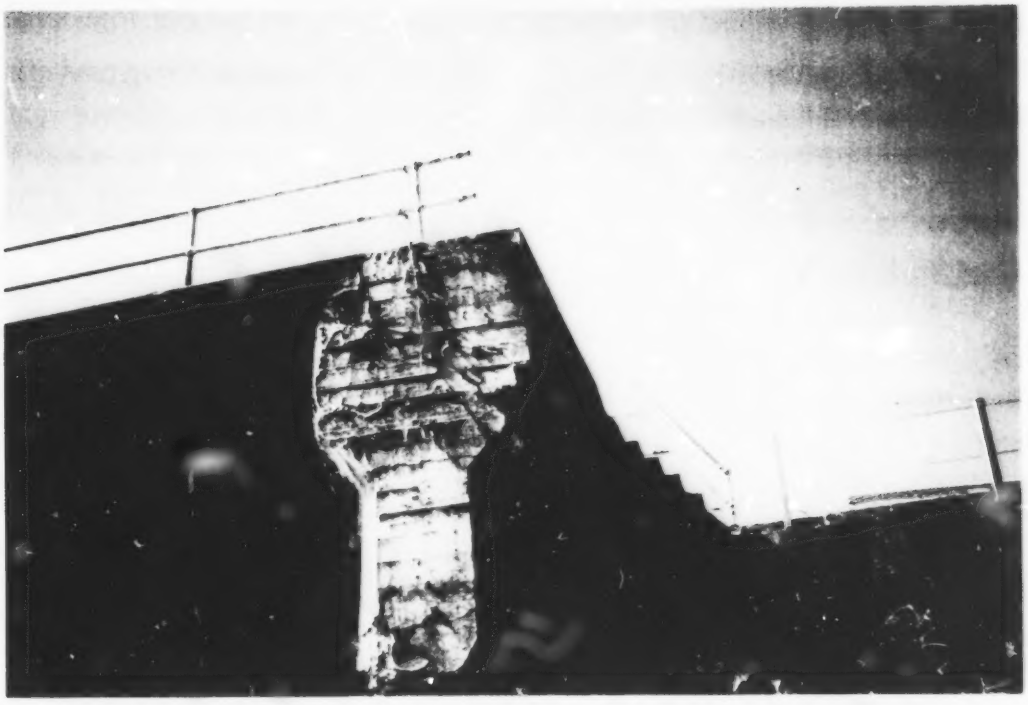


Figure 7: **Cameron Falls GS.** A large crack intersecting the sluiceway east abutment pier.

Figure 8: **Cameron Falls GS.** View of the crack on the east side of the sluiceway east abutment pier. Note the repaired drill holes above (Core 1) and below (Core 2) the crack and the spalled concrete.

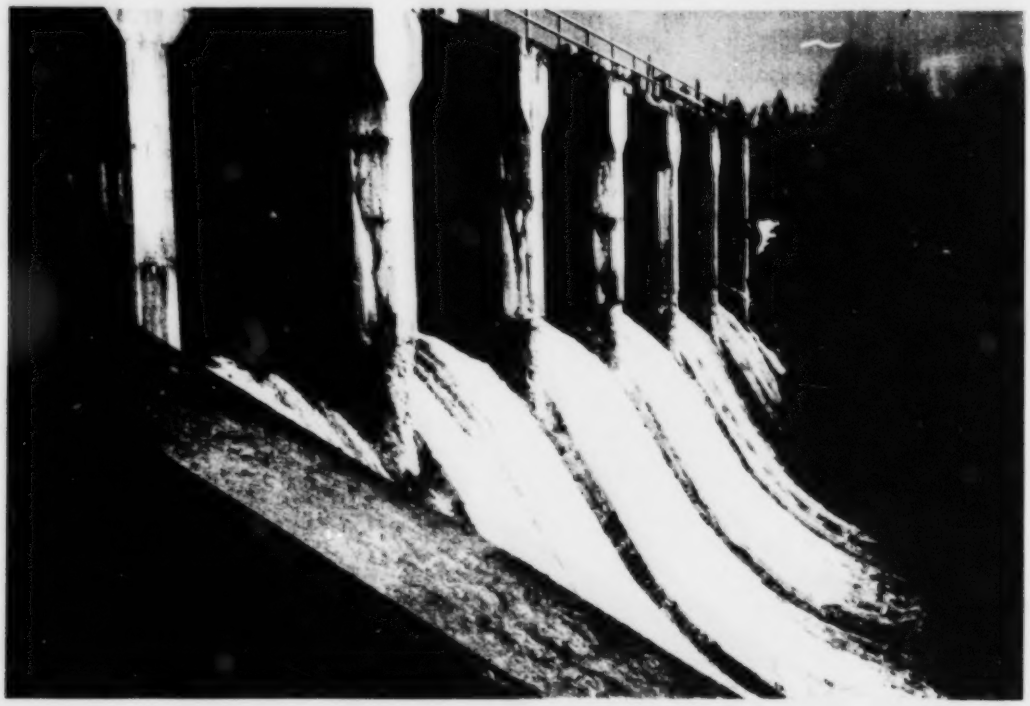


Figure 9: **Cameron Falls GS.** Note the deterioration of the lower portion of the sluiceway piers.

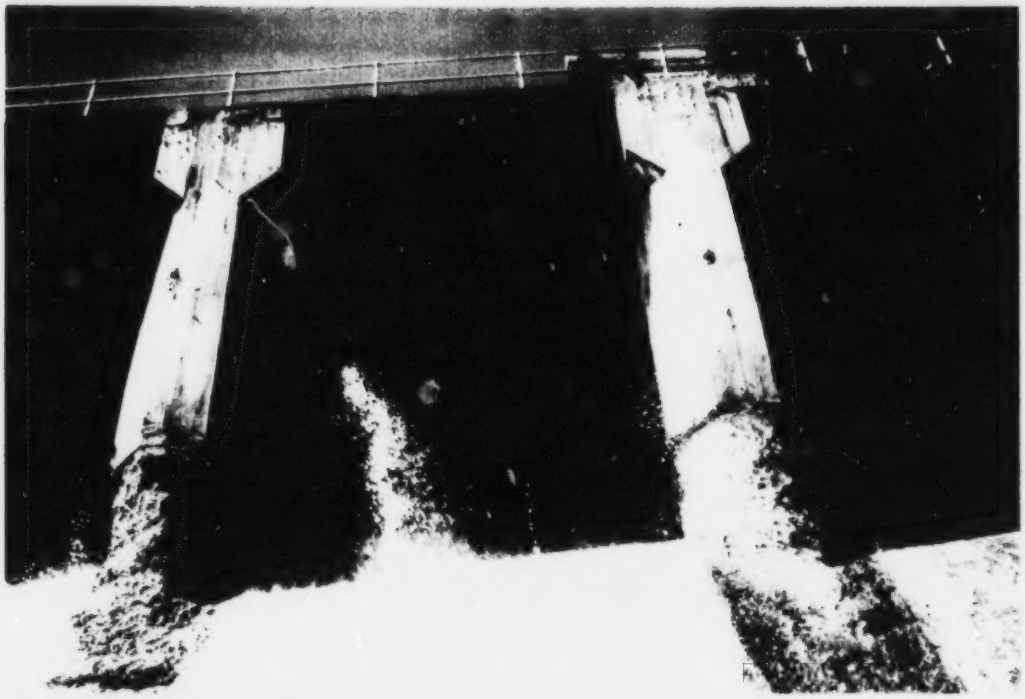


Figure 10: **Cameron Falls GS.** Deterioration of the lower portion of Piers 4 and 5 of the sluiceway.

Figure 11: **Cameron Falls GS.** Crack extending 150 mm into a section of Core 9.

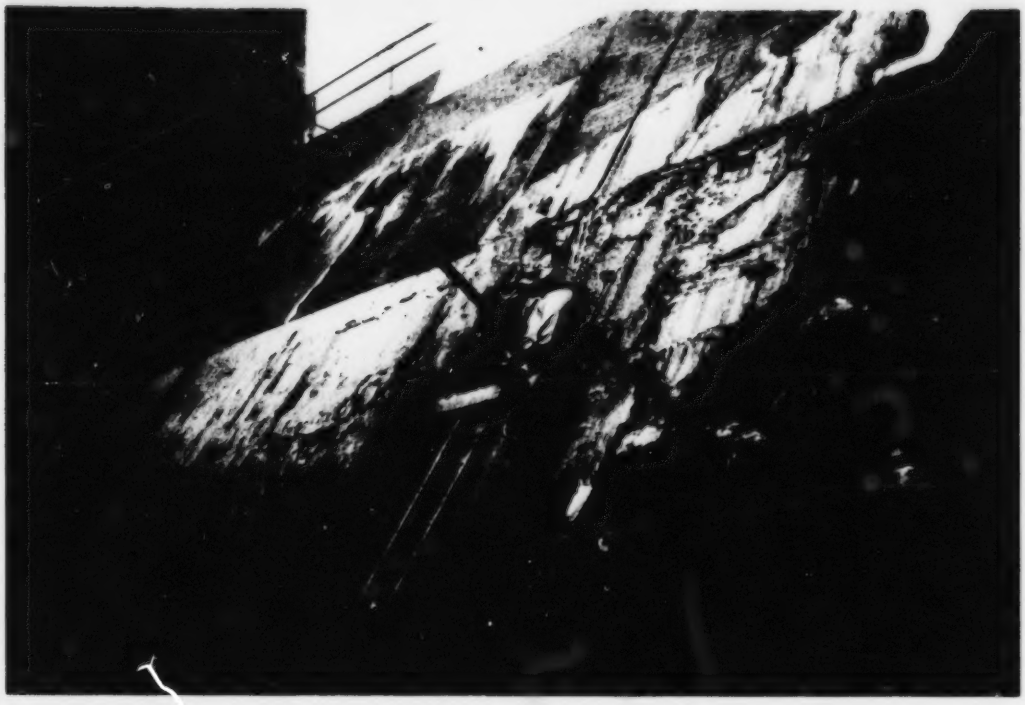


Figure 12: Cameron Falls GS. Drilling Core 11 in the gravity section east of the powerhouse. Note the deposits on the surface of the concrete caused by water seeping through cracks and joints.

Figure 13: Cameron Falls GS. Water flowing at approximately 18 1/min from Borehole 12 in the gravity section east of the powerhouse.

APPENDIX A

ALEXANDER GS TAILRACE PIERS

CORE LOG

TABLE A1

ALEXANDER GS TAILRACE PIERS
CORE LOG

CORE NO.	LOCATION	FROM - TO (mm)	IDENT	DESCRIPTION
1	Pier 1 - Core drilled horizontally 2.0 m below top of deck	0 - 50	1A	-Good concrete -No surface deterioration
		50 - 330	1B	-Good concrete -Maximum aggregate 25 mm
		330 - 355	--	-Core not recovered
2	Pier 1 - Core drilled horizontally 2.0 m below top of deck	0 - 200	--	-Concrete eroded from surface of pier
		200 - 275	2A	-Concrete shows signs of freeze-thaw damage
		275 - 360	2B	-Concrete shows signs of freeze-thaw damage
		360 - 550	2C	-Good concrete -Maximum aggregate 25 mm
		550 - 750	2D	-Good concrete -Maximum aggregate 25 mm -19 mm plain steel bar at 740 mm
		750 - 790	--	-Core not recovered

TABLE A1 (CONTINUED)

ALEXANDER GS TAILRACE PIERS
CORE LOG

CORE NO.	LOCATION	FROM - TO (mm)	IDENT	DESCRIPTION
3	Pier 7 - Core drilled horizontally 2.3 m below top of deck	0 - 130	--	-Concrete eroded from surface of pier
		130 - 400	3A	-Poor concrete -Concrete shows signs of freeze-thaw damage to a depth of 230 mm -Maximum aggregate 25 mm
		400 - 700	3B	-Fair concrete -Poor aggregate distribution -Maximum aggregate 55 mm
		700 - 725	--	-Core not recovered
4	Pier 4 - Core drilled horizontally 1.6 m below top of deck	0 - 230	--	-Concrete eroded from surface of pier
		230 - 270	--	-Core recovered as rubble
		280 - 530	4A	-Poor concrete -Poor aggregate distribution -Maximum aggregate 20 mm -Stopped drilling at 530 mm because of contact with steel
5	Pier 4 - Core drilled horizontally 2.1 m below top of deck	0 - 230	--	-Concrete eroded from surface of pier
		230 - 280	5A	-Poor concrete -Concrete shows signs of freeze-thaw damage
		280 - 550	5B	-Fair concrete -Maximum aggregate 20 mm -Poor aggregate distribution

APPENDIX B

CAMERON FALLS GS MAIN DAM

CORE LOG

TABLE B1

CAMERON FALLS GS MAIN DAM
CORE LOG

CORE NO.	LOCATION	FROM - TO (mm)	IDENT	DESCRIPTION
1	East Abutment Pier - Core drilled horizontally through east face 1.0 m below deck, 1.6 m from south face	0 - 160	1A	-Fair concrete with no surface deterioration -Maximum aggregate 20 mm -Steel (cable) in core
2	East Abutment Pier - Core drilled horizontally through east face 2.0 m below deck, 1.6 m from south face	0 - 10	--	-Concrete eroded from surface of pier
		10 - 190	2A	-Fair concrete -Concrete shows evidence of freeze-thaw damage to 70 mm -Maximum aggregate 30 mm
		190 - 320	2B	-Fair concrete
3	East Abutment Pier - Core drilled horizontally through south face 4.0 m above rollway	0 - 20	--	-Concrete eroded from surface of pier
		20 -120	3A	-Concrete shows evidence of freeze-thaw damage over entire length -Drilling stopped because anchor holding drill failed
4	East Abutment Pier - Core drilled horizontally through south face 3.8 m above rollway	0 - 5	--	-Concrete eroded from surface of pier
		5 - 120	4A	-Fair concrete -Concrete shows evidence of freeze-thaw damage to 105 mm -Maximum aggregate 30 mm

TABLE B1 (CONTINUED)

CAMERON FALLS GS MAIN DAM
CORE LOG

CORE NO.	LOCATION	FROM - TO (mm)	IDENT	DESCRIPTION
4	Cont'd	120 - 300	4B	-Fair concrete
		300 - 325	--	-Core not recovered
5	East Abutment Pier - Core drilled horizontally through south face 1.7 m above rollway	0 - 45	--	-Concrete eroded from surface of pier
		45 - 750	5A	-Fair concrete -Concrete shows signs of freeze-thaw damage to a depth of 75 mm -Maximum aggregate 30 mm
		750 - 1000	--	-Core not recovered
6	Pier 6 - Core drilled horizontally through south face 2.0 m above rollway	0 - 270	6A	-Fair concrete -Maximum aggregate 30 mm -Drilling stopped because of contact with embedded steel plate
		270 - 360	--	-Core not recovered
7	Pier 6 - Core drilled horizontally through south face 2.8 m above rollway	0 - 150	7A	-Good concrete -Maximum aggregate 30 mm
		150 - 180	7B	-Good concrete
8	Pier 3 - Core drilled horizontally through south face 2.1 m above rollway	0 - 50	--	-Concrete eroded from surface of pier
		50 - 75	8A	-Concrete shows evidence of extensive freeze-thaw damage

TABLE B1 (CONTINUED)

CAMERON FALLS GS MAIN DAM
CORE LOG

CORE NO.	LOCATION	FROM - TO (mm)	IDENT	DESCRIPTION
8	Cont'd	75 - 170	--	-Core recovered as rubble -Concrete shows evidence of freeze-thaw damage
		170 - 420	8B	-Poor concrete -Very little coarse aggregate in concrete
		420 - 530	--	-Core not recovered
9	Pier 3 - Core drilled horizontally through south face 2.7 m above rollway	0 - 200	9A	-Fair concrete -Many hairline cracks in surface of pier extending 150 mm into concrete -Maximum aggregate 50 mm
		200 - 330	9B	-Fair concrete
10	Pier 3 - Core drilled horizontally through south face 1.7 m above rollway	0 - 130	--	-Concrete eroded from surface of pier
		130 - 380	--	-Concrete recovered as rubble -Concrete shows evidence of freeze-thaw damage
		380 - 650	10A	-Fair concrete -Maximum aggregate 50 mm -Steel (cable) in core

TABLE B1 (CONTINUED)

CAMERON FALLS GS MAIN DAM
CORE LOG

CORE NO.	LOCATION	FROM - TO (mm)	IDENT	DESCRIPTION
11	Gravity Section - Core drilled horizontally 7.0 m below top of dam, 10.5 m south of powerhouse	0 - 345	11A	-Good concrete -Maximum aggregate 30 mm
		345 - 640	11B	-Good concrete
		640 - 800	11C	-Good concrete -Core broke at 800 mm, interface between repair and original concrete
		800 - 1100	--	-100 mm of rubble recovered from original concrete -Steel (cable) in core -Water flow from drill hole = 4.5 l/min
12	Gravity Section - Core drilled horizontally 1.2 m above grade, 5.5 m south of powerhouse	0 - 290	12A	-Good concrete -Maximum aggregate 40 mm
		290 - 600	12B	-Good concrete -Maximum aggregate 40 mm
		600 - 860	12C	-Good concrete -Core broke at 860 mm, interface between repair and original concrete
		860 - 920	12D	-Concrete shows signs of freeze-thaw damage

TABLE B1 (CONTINUED)

CAMERON FALLS GS MAIN DAM

CORE LOG

CORE NO.	LOCATION	FROM - TO (mm)	IDENT	DESCRIPTION
12	Cont'd	920 - 970	12E	-Fair concrete
		970 - 1260	12F	-Fair concrete -Maximum aggregate 30 mm -Water flow from drill hole = 18 1/min (Flow from Drill Hole 11 stopped after Core 12 was drilled)